RESEARCH HIGHLIGHT

May 2014 Technical Series 14-101

Design and Construction of the Northern Sustainable House – Inuvik, Northwest Territories

INTRODUCTION

To support sustainable housing design in the North, Canada Mortgage and Housing Corporation (CMHC) has worked with northern housing providers to conceptualize, design, build and monitor innovative highly energy-efficient housing projects in each of the three territories. The goals of the NSH initiative are to demonstrate approaches to affordable, energy-efficient, and sustainable housing while addressing the local housing needs and taking into account the interests of future occupants as well as the community and other stakeholders. Each of the demonstration projects followed a similar process whereby input from the local community was sought through an integrated design charrette to ensure input and buy-in from stakeholders. Participants worked to create housing designs that targeted a minimum 50% reduction in the energy consumption relative to the 1997 Model National Energy Code for Houses (MNECH) while striving to address unique cultural needs of the local community in terms of living space functionality.

This highlight provides a summary of the design and construction of the Northern Sustainable House (NSH) in Inuvik, Northwest Territories (N.W.T.). The NSH in Inuvik was designed and built by the Northwest Territories Housing Corporation (NWTHC). The NWTHC provides access to adequate, suitable and affordable housing for Northerners. The Inuvik Housing Authority (IHA) maintains and operates the duplex on behalf of the NWTHC (figure 1).

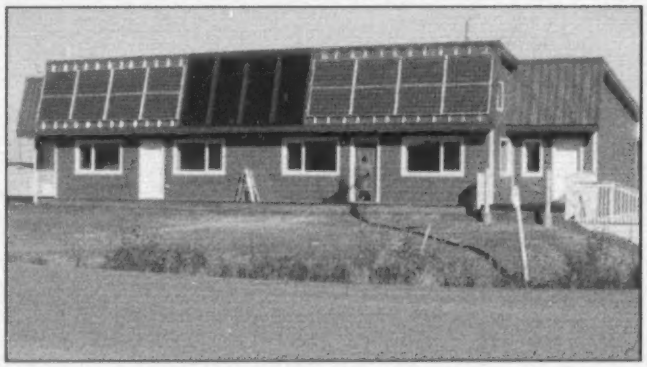

Figure 1 Northern Sustainable House (NSH) in Inuvik, Northwest Territories (N.W.T.)

Design charrette

A housing workshop was held in Inuvik in February 2009, followed by a design charrette in April, to encourage community residents and organizations to contribute their opinions and aspirations regarding the project. Input into the design charrette and workshop came from stakeholder groups including community elders representing both the Gwich'in and the Inuvialuit, participants from the municipal government, educators, students, territorial government employees, contractors, as well as the general public.

Through this process the NWTHC and CMHC had the following objectives:

- To produce a house design (in this case a duplex) that is economical, easy to maintain and possible to construct locally.

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- To develop designs and components that could be implemented in projects in other communities throughout the N.W.T. with relatively minor modifications.
- To design, build and demonstrate a prototype that would meet or exceed an EnerGuide for Houses rating of 85.

Specific design interests provided by the stakeholders through the charrette consultations included:

- single-storey design—to permit accessibility for elders and maintain the traditional "low to the ground" housing design;
- open-concept living space for gatherings of friends or relatives;
- multiple exits for increased safety;
- design to reduce excessive heat gains via south-facing windows in the summer;
- increased heating comfort at floor level; and
- reduction of environmental impact in an effort to live in greater harmony with the environment.

The design team explored and developed a number of floor plan options, including two-storey, one-and-half-storey and one-storey homes. Several highly insulated and airtight wall design options were considered and priced before finalizing on a double-wall assembly. In continuation of the integrated design process in the community of Inuvik, the design team presented a model of the proposed design at the Northern Housing Forum held in Inuvik in March 2010 and then again to the major stakeholders in Inuvik in June 2010.

Design features

The NSH is a one-storey duplex built with an open concept design. The entire duplex is 247 m^2 (2,656 ft^2) with two 119 m^2 (1,277 ft^2) suites and a 9.5 m^2 (102 ft^2) mechanical room, (figure 2). The duplex has a highly insulated building envelope, one high-efficiency condensing boiler, which serves both units, a heat recovery ventilator for each unit, solar thermal hot water system which is run off of glazed flat-plate solar collectors and integrated with the boiler, as well as a 3.6 kW solar photovoltaic system connected to the local power grid.

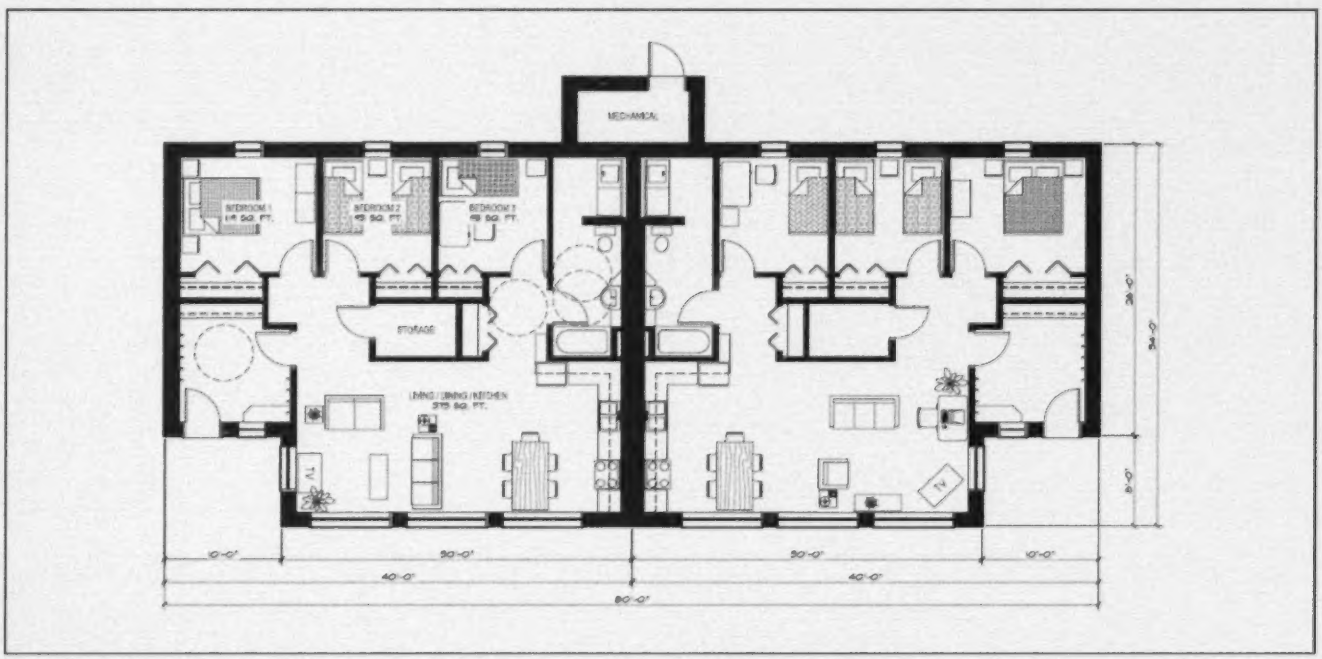

Figure 2 Floor plan from the Northern Sustainable House in Inuvik (Credit: NWTHC)

Structural

The duplex is constructed on a space frame foundation made out of rigid steel tubing, supported by footings on a gravel pad. The site was prepared in October 2009 by the NWTHC. After the space frame was installed, a unique structural insulated panel (SIP) floor system was shipped and installed in December 2010. The prefabricated SIP system allowed for quick assembly on site and achieved a thermal insulation level of RSI-9.3 (R 53) and good airtightness.

The custom-ordered, high-heel roof trusses were designed to accommodate additional attic insulation, especially at the rear of the house where the roof deck to finished ceiling height is the lowest. Additionally, the high heel roof trusses also allow for a steeper tilt angle for the solar panels (75°).

Envelope

The duplex was designed with a highly insulated building envelope (figure 2):

- Double-stud wall assembly RSI-8.1 (R 46)
- Main and storm doors at RSI-0.98 (R 5.6)
- Windows on the north RSI-0.97 (R 5.5, rear of the house) and south RSI-0.74 (R 4.2, front of the house)
- Ceiling designed at RSI-14.1 (R 80)
- Floor above crawl space RSI-9.3 (R 53)

The double-stud wall construction was chosen among several wall assemblies given its improved thermal performance, moderate incremental cost, use of local labour, relative ease in assembling, conventional building materials and low fire load (mineral wool insulation). Thermal bridges were minimized by staggering the studs of the interior and exterior wall frames.

Space heating

The duplex has one high-efficiency condensing modulating natural gas boiler that meets the space heating needs and the domestic hot water demand of both units. One pump-controlled heating loop passes through each housing unit. A controller regulates the water temperature of the boiler based on outdoor temperature to allow the heating system to respond more quickly to changing outdoor temperature.

The two units in the duplex share a common mechanical room (figure 3), which is located at the back of the house with a separate entrance from the outside. This design is advantageous for noise control and fire protection while providing access to the mechanical room for maintenance and service without having to disturb the occupants of either unit.

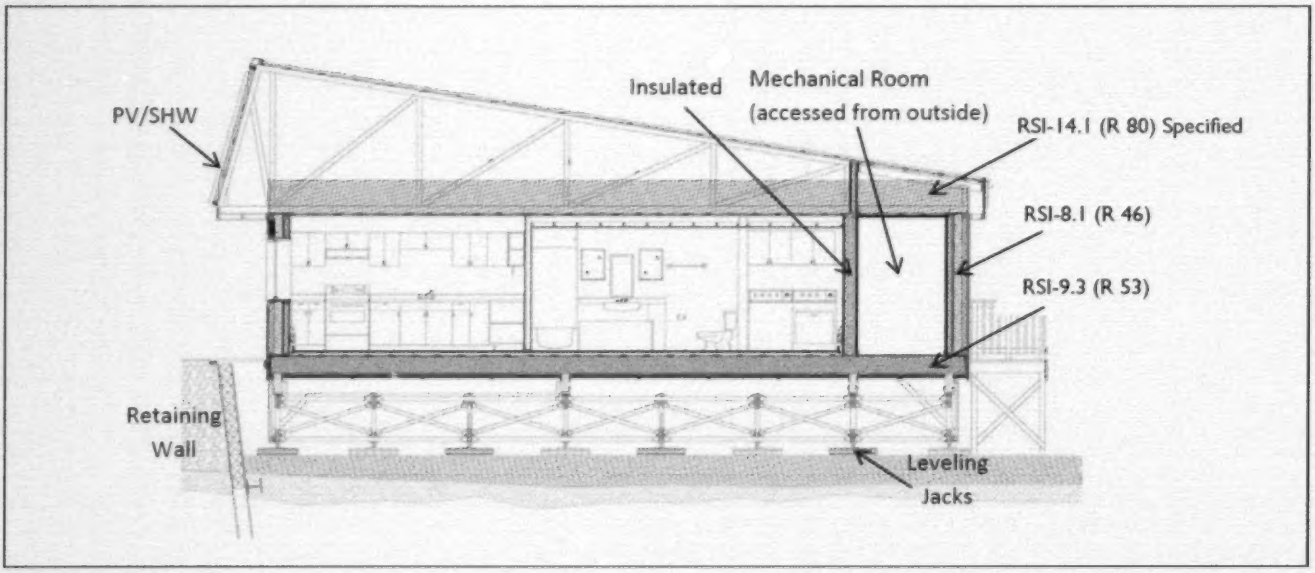

Figure 3 Building section of the NSH (Credit: NWTHC)

Solar domestic hot water (SDHW) system

The hot water is preheated by four glazed flat-plate solar collectors. A double-wall heat exchanger transfers heat from the panel loop to the storage tank loop. The preheated water then flows to a domestic hot water tank where it is further heated via a loop from the boiler as needed.

Mechanical ventilation

Each housing unit has a mechanical heat recovery ventilation (HRV) system that provides preheated fresh air to every room. The exhaust is drawn from the bathrooms and kitchens and fed back into the HRV. A hydronic preheat coil was installed in the intake ducts to condition very cold outdoor air before it reaches the HRV core. This is intended to prevent core freeze-up and ensure the temperature of the ventilation air entering the units is at a comfortable temperature for the occupants.

Solar photovoltaic

Each housing unit has eight, 224 W, solar photovoltaic modules installed at 75° tilt directly resting on the roof, for a total nameplate capacity of 1,792 watts per unit. A grid tie inverter converts the direct current (DC) power from the PV array to alternating current (AC) power. The solar-generated electricity is first consumed by loads within the house and the excess generation is fed back into the grid via a bidirectional meter.

Energy Modelling of design options for the NSH

The NWTHC set a design objective to meet an EnerGuide for Houses (EGH) rating of 85 (Natural Resources Canada, 2011) and at least a 50% reduction in energy consumption relative to the 1997 Model National Energy Code for Houses. Natural Resources Canada's HOT2000 residential energy consumption simulation tool was used to model the final construction of the duplex. The modelling indicated that the NSH achieved an EGH rating of 87 thereby exceeding the target by 2 EGH points. According to HOT2000, each unit of the duplex is expected to consume 7,040 kWh of electricity and 46 GJ of natural gas per year. At current rates (June 2013), this was estimated to represent $4,770 for electricity and $1,980 for natural gas per year per unit.

The RETScreen® analysis estimated that the eight-panel PV system for each unit would offset approximately 2,040 kWh of purchased electricity per unit per year. This represents annual cost savings of about $1,385 per unit and reductions in greenhouse gas emissions of about 1.23 tCO_2e (tonnes of CO_2 equivalent) per unit.

The RETScreen analysis also estimated that the two-panel SDHW system for each unit would yield an annual natural gas savings of approximately 12.6 GJ per unit, an annual cost savings of about $540 per unit (at a gas rate of $41/GJ) and reductions in annual greenhouse gas emissions of 0.5 tCO_2e per unit (as of June 2013).

Compared to an equivalent house in Inuvik built to the standards of 1997 MNECH, the Northern Sustainable House is projected to save $5,800 on electricity bills and $2,100 on natural gas bills annually at the rate paid by the Inuvik Housing Authority (June 2013).

Table 1 Construction costs (estimated)

TOTAL	**$1,026,165**
Site preparation and retaining wall	$150,000
Land cost	$0
Total house construction cost	**$876,165**
Tender price -including solar components but not solar commissioning, excluding site, land, space frame materials	$813,000
Space frame -space frame materials cost not included in tender	$55,000
Solar commissioning	$8,165

The total incremental costs of key sustainable features were estimated at $228,101. This cost includes the estimated increased costs of $169,976 for additional materials, installation time and shipping of the SIP panel floor system, the double-wall system, special order high-heel trusses, increased insulation in attic space, fibreglass doors, triple-pane fibreglass windows (as opposed to double-pane), quad-pane fibreglass windows, high efficiency boiler, hot water tank and mechanical systems and HRVs. Solar hot water components, PV components and commissioning, also included in the total incremental costs, were estimated at $58,000.

CONCLUSION

As evaluated by the HOT2000 model, each unit of the duplex would achieve an EnerGuide for Houses rating of 87, fulfilling the goal of EGH 85 as part of the design objective. This rating would put these units in the same category as some of the most energy-efficient new houses currently on the Canadian market. Compared to an equivalent house in Inuvik built to the standards of 1997 MNECH, the Northern Sustainable House is projected to consume approximately $5,800 (8,600 kWh) less in electricity and $2,100 (49 GJ) less in natural gas annually (as of June 2013).

Implications for the Housing Industry

This project demonstrates that sustainable housing technologies and practices can be successfully deployed within the very challenging context of northern housing. In this respect, integrated design charrettes have a role to play in transforming local industry and consumer, attitudes, awareness and knowledge regarding higher performance housing. Active engagement of all stakeholders from planning through to the commissioning can help innovative housing projects meet their objectives. The project also demonstrated the importance of quality assurance protocols to help ensure materials and systems are installed as planned and performed as expected. Finally, the project shows how solar energy systems and other technologies and practices can be applied to housing projects in the Far North and the challenges associated with the deployment and maintenance of such systems.

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Consultant: Arctic Energy Alliance

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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